

## Appendix A: Knowledge assumed to be in place prior to stage 2 US training

### A.1: Mathematics

#### *Algebra:*

- elements of algebra – arithmetic; positive integral exponents; zero, fractional and negative exponents
- functions – variables as symbols; functions; single valued functions; functions with variables.
- functions and loci – function as a collection of numbers; the rectangular Cartesian coordinate system; the graph of a function;.
- the linear equation – equations; solving an equation; ratio and proportion; variation.
- simultaneous linear equations – two linear equations and two unknowns; graphical solution; algebraic solution; three linear equations in three unknowns; solutions of linear systems using detached coefficients.
- quadratic functions and equations – graphs of quadratic functions; a quadratic equation with one unknown; equations in quadratic form;
- arithmetic and geometric progressions – a sequence is a set of numbers, an arithmetic progression, the terms between the first and last terms, a geometric progression, the terms between the first and last terms
- logarithms – the logarithm of a positive number; fundamental laws of logarithms; common logarithms; the cologarithm; an exponential equation; natural logarithms; four place common logarithms.
- power, logarithmic and exponential curves – curves of power functions; curves of logarithmic functions; curves of exponential functions.

#### *Trigonometry:*

- angles and arc length – the plane angle; measures of angles; arc length.
- trigonometric functions of a general angle – angles in standard position; trig functions of a general angle; algebraic signs of the functions; trig functions of quadrantal angles.
- trigonometric functions of an acute angle – trig functions of an acute angle; trig functions of complementary angles; trig functions of  $30^{\circ}$ ,  $45^{\circ}$ ,  $60^{\circ}$ .
- practical applications – the bearing of a point measured from a known point, vectors, vector addition, the component of a vector
- calculations in trigonometric functions – approximate values of the functions; natural trig functions; find the value of a function; find the angle of a function; errors and accuracy in computed results
- fundamental relations and identities – fundamental relations; simplification of trig expressions; trig identities.
- trigonometric functions of two angles – addition; subtraction; double-angle; half-angle.
- sum difference and product formulas – products of sines and cosines; sum and difference of sines and cosines.
- Oblique triangles, non-logarithmic solutions – an oblique triangle; the law of sines; Mollweide's formulas; projection formulas; the law of cosines.
- Logarithmic solutions of oblique triangles – the law of tangents; half-angle formulas.

#### *Analytical geometry:*

- coordinates and loci – the projection of the line segment; the length of a line segment; a point on a line segment; the slope of a straight line; the angle between two lines; the area of a triangle.
- the straight line – the equation of a straight line; the general equation; the normal form; reduce the general equation; the directed distance.
- family of straight lines – equations.
- the circle – a circle is a locus, the standard form; the general form; both forms; the equation of a tangent; the length of a tangent; the radical axis of two circles.
- the parabola – equations.
- the ellipse – equations.
- the hyperbola – equations.

- polar coordinates – the polar coordinate system; transformation between polar and rectangular coordinates; curve tracing in polar coordinates; intersection of polar curves.
- parametric equations – a third unknown in two equations, path of a projectile.

***Plane and solid geometry:*** (centre of gravity – cog; moment of inertia – moi)

- Triangles – area; perimeter; cog, moi.
- Pyramids – surface area; volume; frustum; cog, moi.
- Cones – surface area; volume; frustum; cog, moi.
- circles - area; perimeter; sector; segment; cog, moi.
- spheres – surface area; volume; segments; zones; cog, moi.
- cylinders – surface area; volume; thick wall; thin wall; cylindrical wedge; cog, moi.
- Ring (torus) – surface area; volume; cog, moi.
- rectangles - area; perimeter; cog, moi.
- cuboids – surface area; volume; tubing; cog, moi.
- Trapezoid - area; perimeter; cog, moi..
- Ellipse – area; perimeter; cog, moi.
- Parallelogram - area; perimeter; cog, moi.
- Regular polygon – area; perimeter; cog, moi.
- Prism – surface area; volume; cog, moi.

## **A.2: Applied mathematics**

### ***SI units***

2.01 Exponential manipulation, multiples and fractions of units.

2.02 Basic units Length, mass, time, electric current, temperature, substance, luminous intensity.

2.03 Derivatives The 67 derivatives are discussed in the following sections - #[basic equations]

### ***Basic applied mathematics***

2.04 Basic electrical knowledge

DC [current, voltage, resistance, resistivity, conductance, networks]

AC [DC + frequency, period, peak & RMS values, single and three phase equations, phase angle, vectors, networks]

Magnetism [magnetic flux, magnetic induction, magnetic field strength, magnetomotive force, reluctance, inductance, simple motors and generators]

Electric field [ quantity, capacitance,]

Power [ energy , power, apparent power, power factor]

Semi-conductors [transistors, rectifiers, thyristors, triacs, diodes, surge arrestors]

2.05 Basic mechanical knowledge

Kinematics [length, time, frequency, period,]

Linear motion [velocity, speed, distance, acceleration, force, momentum, inertia, projectiles, vectors]

Rotational motion [angle, speed, acceleration, inertia, torque, tangential forces, centripetal forces and centrifugal forces, vibration]

Harmonic motion [Position, velocity, acceleration,]

Energy [ work, kinetic and potential energy, power,]

Forces [definition, addition, graphical and mathematical composition, resultants, gravitational, conditions of equilibrium, moments, lever action]

Friction [ coefficient of friction, angle of friction, dynamic friction]

2.06 Basic fluid mechanics [pressure, pressure distribution, forces, density, viscosity, buoyancy, friction flow,]

2.07 Thermodynamics [laws, pressure, temperature, density, molecular volume, heat, expansion of bodies, enthalpy, entropy, specific heat, gas constant, standard temperature and pressure, heat transfer rate, transfer resistance, transfer conductance,]

2.08 Strength of Materials [Forces, stresses, strain, Young's modulus, thermal stresses, second moment of area, catenaries, fatigue failure, mechanical and chemical properties of metals, testing of materials,]

### A.3 The SI units and derivatives with special names

Table 1 Basic SI units

| Quantity                  | Unit     | Symbol |
|---------------------------|----------|--------|
| Length                    | metre    | m      |
| Mass                      | kilogram | kg     |
| Time                      | second   | s      |
| Electric current          | ampere   | A      |
| Thermodynamic temperature | kelvin   | K or C |
| Amount of substance       | mole     | mol    |
| Luminous intensity        | candela  | cd     |

Table 2 SI derivatives with special names

| Quantity                | Name    | Symbol   | Expression in terms of other Si units |
|-------------------------|---------|----------|---------------------------------------|
| admittance              | siemens | S        | $\Omega^{-1}$                         |
| capacitance             | farad   | F        | C/V                                   |
| conductance             | siemens | S        | $\Omega^{-1}$                         |
| electric charge         | coulomb | C        | A-s                                   |
| electric flux           | coulomb | C        | A-s                                   |
| electric potential      | volt    | V        | W/A                                   |
| electrical resistance   | ohm     | $\Omega$ | V/A                                   |
| electromotive force     | volt    | V        | W/A                                   |
| energy                  | joule   | J        | N-m                                   |
| energy flux             | watt    | W        | J/s                                   |
| flux of displacement    | coulomb | C        | A-s                                   |
| force                   | newton  | N        | kg-m/s <sup>2</sup>                   |
| frequency               | hertz   | H        | s <sup>-1</sup>                       |
| illuminance             | lux     | lx       | lm/m <sup>2</sup>                     |
| impedance               | ohm     | $\Omega$ | V/A                                   |
| inductance              | henry   | H        | Wb/A (V-s/A)                          |
| luminous flux           | lumen   | lm       | cd-sr                                 |
| magnetic flux           | weber   | Wb       | V-s                                   |
| magnetic flux density   | tesla   | T        | Wb/m <sup>2</sup>                     |
| magnetic induction      | tesla   | T        | Wb/m <sup>2</sup>                     |
| magnetic polarization   | tesla   | T        | Wb/m <sup>2</sup>                     |
| permeance               | henry   | H        | Wb/A (V-s/A)                          |
| potential difference    | volt    | V        | W/A                                   |
| power                   | watt    | W        | J/s                                   |
| pressure                | pascal  | Pa       | N/m <sup>2</sup>                      |
| quantity of electricity | coulomb | C        | A-s                                   |
| quantity of heat        | joule   | J        | N-m                                   |
| reactance               | ohm     | $\Omega$ | V/A                                   |
| stress                  | pascal  | Pa       | N/m <sup>2</sup>                      |
| susceptance             | siemens | S        | $\Omega^{-1}$                         |
| weight                  | newton  | N        | kg-m/s <sup>2</sup>                   |
| work                    | joule   | J        | N-m                                   |

Mechanical energy must not be expressed in newton metres (N-m) but only in joules (J).  
the

N-m is used only for torque or moment of force.

Table 3 SI units without special names

| Quantity                        | SI unit                           | Symbol                              |
|---------------------------------|-----------------------------------|-------------------------------------|
| acceleration                    | metre per second squared          | $\text{m/s}^2$                      |
| angular acceleration            | radian per second squared         | $\text{rad/s}^2$                    |
| angular momentum                | kilogram metre squared per second | $\text{kg}\cdot\text{m}^2/\text{s}$ |
| angular velocity                | radian per second                 | $\text{rad/s}$                      |
| area                            | square metre                      | $\text{m}^2$                        |
| coefficient of heat transfer    | watt per metre squared kelvin     | $\text{W}/\text{m}^2\cdot\text{K}$  |
| coefficient of linear expansion | 1 per kelvin                      | $\text{K}^{-1}$                     |
| conductivity                    | siemens per metre                 | $\text{S}/\text{m}$                 |
| density                         | kilogram per cubic metre          | $\text{kg}/\text{m}^3$              |
| dynamic viscosity               | pascal second                     | $\text{Pa}\cdot\text{s}$            |
| electric charge density         | coulomb per cubic metre           | $\text{C}/\text{m}^3$               |
| electric current density        | ampere per square metre           | $\text{A}/\text{m}^2$               |
| electric field strength         | volt per metre                    | $\text{V}/\text{m}$                 |
| heat capacity                   | joule per kelvin                  | $\text{J}/\text{K}$                 |
| heat flux density               | watt per square metre             | $\text{W}/\text{m}^2$               |
| kinematic viscosity             | metre squared per second          | $\text{m}^2/\text{s}$               |
| luminance                       | candela per square metre          | $\text{cd}/\text{m}^2$              |
| magnetic field strength         | ampere per metre                  | $\text{A}/\text{m}$                 |
| magnetic moment                 | ampere per metre square           | $\text{A}/\text{m}^2$               |
| mass flow rate                  | kilogram per second               | $\text{kg}/\text{s}$                |
| mass per unit area              | kilogram per square metre         | $\text{kg}/\text{m}^2$              |
| mass per unit length            | kilogram per metre                | $\text{kg}/\text{m}$                |
| moment of force                 | newton metre                      | $\text{N}\cdot\text{m}$             |
| moment of momentum              | kilogram metre squared per second | $\text{kg}\cdot\text{m}^2/\text{s}$ |
| momentum                        | kilogram metre per second         | $\text{kg}\cdot\text{m}/\text{s}$   |
| permeability                    | henry per metre                   | $\text{H}/\text{m}$                 |
| permittivity                    | farad per metre                   | $\text{F}/\text{m}$                 |
| resistivity                     | ohm metre                         | $\Omega\cdot\text{m}$               |
| specific energy                 | joule per kilogram                | $\text{J}/\text{kg}$                |
| specific heat capacity          | Joule per kilogram kelvin         | $\text{J}/\text{kg}\cdot\text{K}$   |
| speed (velocity)                | metre per second                  | $\text{m}/\text{s}$                 |
| surface tension                 | newton per metre                  | $\text{N}/\text{m}$                 |
| thermal conductivity            | watt per metre kelvin             | $\text{W}/\text{m}\cdot\text{K}$    |
| torque                          | newton metre                      | $\text{N}\cdot\text{m}$             |
| volume                          | cubic metre                       | $\text{m}^3$                        |

**A.6 Engineering** Stage 2 knowledge required for US and US exposure. (# means referring to)

**1.00 Electrical Technology**

- 1.01 Direct current machines Basic equations #[A.2 par. 2.01 to 2.04], types, motors, generators, characteristics, efficiency, control circuits
- 1.02 Transformers Basic equations #[A.2 par. 2.01 to 2.04], types, no-load & short-circuit tests, equivalent diagram, power factor, efficiency, parallel connection,
- 1.03 Induction machines Basic equations #[A.2 par. 2.01 to 2.04], types, single and three phase, performance, slip, power, torque characteristic, current diagram, power factor, equivalent diagram, efficiency, control circuits,
- 1.04 Synchronous machines Basic equations #[A.2 par. 2.01 to 2.04], characteristics, power factor, power, phase angle, efficiency, control circuits, generation of power,
- 1.05 Transmission lines Basic equations #[A.2 par. 2.01 to 2.04, 2.08], power transfer, regulation, protection, insulators, catenaries,
- 1.06 Power distribution Basic equations #[A.2 par 2.01 to 2.04], economics, power factor, maximum demand, cables, circuit breakers, electrical protection, fault current calculations, harmonics
- 1.07 Lightning basic equations #[A.2 par 2.01 to 2.04], protection, earthing, transients

**2.00 Mechanical Technology**

- 2.01 Transport Basic equations #[A.2 par. 2.01 to 2.03 and 2.05, 2.08], trackless and track bound vehicles, scraper winches, brakes, clutches, engine power, diesel engines, inclines, road and track designs, type of transport for men, mineral and material, endless rope haulages, chimes wheel, chutes, factor of safety on connections
- 2.02 Winding Basic equations #[A.2 par 2.01 to 2.03, 2.04, 2.05, 2.08], types of winders, protection, control, programmable controllers, ropes, brakes, clutches, cycle times, cycle characteristics, sheave wheels, head gears, mine shafts, cages, skips.
- 2.03 Conveyors Basic equations #[A.2 par. 2.01 to 2.03, 2.04, 2.05, 2.08], design parameters, tensioning devices, guarding, transport of men and mineral, protection devices
- 2.04 Elevators Basic equations #[A.2 par. 2.01 to 2.03, 2.04, 2.05, 2.08] multi ropes, counterpoise, protection, control, programmable controllers, hatchway and hatchway devices,
- 2.05 Chair lifts Basic equations #[A.2 par 2.01 to 2.03, 2.04, 2.05, 2.08], design and operational requirements, counterpoise,
- 2.05 Lifting equipment Basic equations #[A.2 par. 2.01 to 2.03, 2.04, 2.05, 2.08], cranes, rope blocks, chain blocks, slings
- 2.06 Power transmission Basic equations #[A.2 par. 2.01 to 2.03, 2.05, 2.08], gears and chain drives, V-belt drives, rope pulleys, clutches, gearboxes, braking systems, couplings, shafts,
- 2.07 Bearings Basic equations #[A.2 par 2.01 to 2.03, 2.05, 2.06], journal, roller, ball, tapered

**3.00 Fluid Mechanics**

- 3.01 Flow of fluid Basic equations #[A.2 par 2.01 to 2.03, 2.06], conservation of mass, volume, power, transmission of energy, momentum, friction in pipes and launders, aperture flow, orifices, equivalent head, hydraulic circuits and machines,
- 3.02 Lubrication Basic equations #[A.2 par 2.01 to 2.03, 2.06], properties of oils and

|  |   |
|--|---|
| 3.03 Pumping systems                   | greases, viscosity of oils, viscous flow, selection of lubricants, Basic equations #[A.2 par 2.01 to 2.03, 2.04, 2.06], types of pumps, power, pump characteristics, nett positive head, specific speed, material transmission, pelton wheel, dams, water distribution, settlers, |
| <b>4.00 Thermodynamics</b>             |   |
| 4.01 Refrigeration                     | Basic equations #[A.2 par. 2.01 to 2.03, 2.04, 2.07], types of systems, enthalpy of fusion, Carnot cycle, coefficient of performance, gas properties, air conditioning, refrigerant properties,   |
| 4.02 Compressed air                    | Basic equations #[A.2 par. 2.01 to 2.03, 2.04, 2.07], friction flow, auto compression, columns, receivers, compressors, blowers, motors,  |
| 4.03 Steam                             | basic equations #[A.2 par 2.01 to 2.03, 2.07], properties, flow, entropy of water, work, piping, energy, throttling, boilers and ancillary equipment, turbines, heat exchangers, cooling towers,  |
| 4.04 Internal combustion engines       | Basic equations #[A.2 par 2.01 to 2.03, 2.07], applications, power, efficiency, fuels,  |
| <b>5.00 Strength of Materials</b>      |   |
| 5.01 Beams                             | Basic equations #[A.2 par 2.01 to 2.03, 2.08], shearing force, bending moments, bending stresses, moments of inertia, composite beams   |
| 5.02 Shafts                            | Basic equations #[A.2 par 2.01 to 2.03, 2.08], torsional stress, transfer of power, bending stress, axial loads, polar moment of inertia, angle of twist,   |
| 5.03 Struts                            | Basic equations #[A.2 par 2.01 to 2.03, 2.08], slenderness ratio,   |
| 5.04 Concrete                          | Basic equations #[A.2 par 2.01 to 2.03, 2.08], stress and strain characteristics, wear resistance, reinforcing, quality control, curing, mixes,   |
| 5.05 Fasteners                         | Basic equations #[A.2 par 2.01 to 2.03, 2.08], screws and bolts, rivets, welded joints,   |
| <b>6.00 Springs</b>                    |   |
| 6.01 Leaf springs                      | Basic equations #[A.2 par 2.01 to 2.03, 2.08], semi-elliptic, quarter-elliptic,   |
| 6.02 Helical springs                   | Basic equations #[A.2 par 2.01 to 2.03, 2.08], closed coil  |
| <b>7.00 Environmental requirements</b> |   |
| 7.01 Illumination                      | <u>Luminous flux</u> , - intensity, - efficiency, illuminance, luminance, luminaries  |
| 7.02 Ventilation                       | Purpose, air flow, humidity, fans, fan characteristics, dilution of flammable gasses  |
| 7.03 Dust                              | Properties and effects, dusting, filters, pollution   |
| 7.04 Water                             | Quality, purification, pollution, storage dams  |
| 7.05 Noise                             | Dangers, monitoring, suppression methods,   |
| 7.06 Waste disposal                    | Identification symbols, transport, storage, handling  |
| 7.07 Hazardous chemicals               | storage, use, disposal  |
| 7.08 Waste rock dumps                  | Safety measures, building and removal of the dump, rehabilitation   |
| 7.09 Slimes dams                       | Safety measures, operation, control of pollution, rehabilitation  |
| 7.10 Explosive atmospheres             | Classification and selection of equipment, requirements of engines and spark free materials, identification markings, <u>requirement for electrical equipment</u> , - cables, - cap lamps, - hand tools,  |
| 7.11 Corrosion                         | Principles, prevention techniques,  |

## **8.00 Safety and Management**

- 8.01 Fire protection Types of fire extinguishers, systems,
- 8.02 Risk management Scope, identification of hazards, evaluation, risk estimation, - analysis,  
- control, audits, accident and incident analysis
- 8.03 Project management Project definition, network scheduling, critical path, program evaluation and review technique, project control, tenders and contracts.
- 8.04 Financial management Cost of repair, nett present value, rate of return, budget control
- 8.05 Maintenance Planned maintenance, reliable centred maintenance, preventative maintenance, life cycle costs
- 8.06 Drawings Elementary machine drawings, network schematic diagrams
- 8.07 Safety behaviour Codes of practices, accident analysis (procedures are filed in the respective topics)